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Environmental Radioactivity in the Faroes in 1965

by

A. Aarkrog and J. Lippert

The Danish Atomic Energy Commission
Research Establishment Risø
Health Physics Department

Abstract

The present report deals with the measurement of fall-out radioactivity in the Faroes in 1965.

Sr-90 (and Cs-137 in most instances) was determined in regularly collected samples of precipitation, milk, potatoes, sheep, fish, drinking water, and deciduous teeth. In addition, analyses of spot samples of grass, soil, sea water, sea plants, birds, vegetables, bread, cheese, and eggs were carried out.

Estimates of the mean contents of Sr-90 and Cs-137 in the human diet in the Faroes in 1965 are given.

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Acknowledgements

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Finally we thank Mr. Flemming Steenbuch, who has been very helpful with the correction of the language in this report.

Abbreviations and Units

FP	fission products
pCi	picocurie, 10^{-12} Ci, μμCi
nCi	nanocurie, 10^{-9} Ci, mμCi
mCi	millicurie, 10^{-3} Ci
MPC	maximum permissible concentration
S. U.	pCi Sr-90/g Ca ("Sunshine unit")
O. R.	Observed ratio
M. U.	pCi Cs-137/g K ("Moonshine unit")
n Sr	natural (stable) Sr
S. D.	standard deviation $\sqrt{\frac{\Sigma(x-x_i)^2}{(n-1)}}$
S. E.	standard error $\sqrt{\frac{\Sigma(x-x_i)^2}{n(n-1)}}$
S. S. D.	sum of squares of deviations $\Sigma(x-x_i)^2$
f	degrees of freedom
s^2	variance
v^2	ratio between the variance in question and the residual variance
P	probability of the distribution in question
$\bar{x}$	mean values
Σ	sum
¶	coefficient of variation.

1. INTRODUCTION

1.1.

The fall-out programme for the Faroes, which was initiated in 1962[1] in close co-operation with the National Health Service and the chief physician of the Faroes, was continued with only a few alterations in 1965.

1.2.

The present report will not repeat information concerning sample collecting and analysis already given in Risö Reports Nos. 64[1], 86[2] and 108[3].

1.3.

The mean diet of the Faroese as used in this report is unchanged as compared with 1962, i.e., it is still based on the estimate given by Professor E. Hoff-Jørgensen, Ph.D., nutritional consultant to the Danish Atomic Energy Commission.

1.4.

The present investigation was carried out along with corresponding examinations of fall-out levels in Denmark and Greenland, described in Risö Reports Nos. 130[4] and 132[5] respectively.

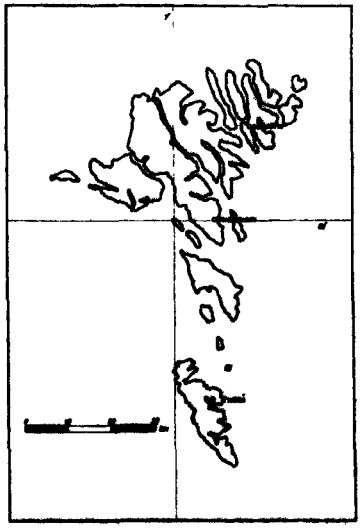

Fig. 1.1. The Faroes.

2. RESULTS AND DISCUSSION

2.1. Sr-90 in Precipitation

Table 2.1 shows the Sr-90 content in precipitation collected at Høyvig (near Thorshavn) and Klaksvig in 1965. The amount of precipitation at Klaksvig was a factor of 2.7 greater than that found at Høyvig, and the amount of fall-out at Klaksvig was 2.4 times that measured at Høyvig.

The mean specific activity of Sr-90 in precipitation in 1965 was 34% of the 1964 level in the Faroes. This is in close agreement with the ratio between 1965 and 1964 rain activity in Denmark[4], which was found to be 36%. The mean fall-out in the Faroes in 1965 was 32% of that in 1964.

Table 2.1

Sr-90 in Precipitation from the Faroes in 1965

	Høyvig		Klaksvig		Mean	
	pCi Sr-90/l	mCi Sr-90/km^2	pCi Sr-90/l	mCi Sr-90/km^2	pCi Sr-90/l	mCi Sr-90/km^2
Jan.	7.31	0.64	5.21	0.81	6.2	0.72
Feb.	9.87	0.34	11.6	0.74	10.8	0.49
Mar.	9.47	0.53	8.80	1.85	9.0	1.19
Apr.	7.43	0.41	8.52	1.13	7.9	0.77
May	8.87	0.48	13.3	1.04	11.1	0.76
June	10.4	0.80	8.07	1.15	9.2	1.02
July	10.0	0.26	23.0	0.53	16.5	0.40
Aug.	6.04	0.50	5.50	1.32	5.8	0.91
Sep.	3.96	0.30	3.73	0.97	3.8	0.64
Oct.	3.33	0.32	3.65	0.89	3.5	0.60
Nov.	2.63	0.18	2.84	0.48	2.2	0.33
Dec.	2.11	0.12	3.45	0.68	2.3	0.50
	$\bar{x}$	Σ 731 mm	$\bar{x}$	Σ 1990 mm	$\bar{x}$	Σ 1356
1965	6.68	4.88	8.96	11.79	6.15	8.33

The relative error of the results was approx. 10%.

$\bar{x}$ pCi/l = $\frac{\text{mCi/km}^2 \cdot 1000}{\text{mm}}$.

Table 2.2

Sr-90 and Cs-137 in Grass from Thorshavn in 1965

Month	pCi Sr-90/g ash	pCi Sr-90/kg	pCi Sr-90/g Ca	nCi Cs-137/kg	pCi Cs-137/g K	Cs-137/Sr-90
June	59 ± 1	2160 ± 30	1160 ± 130	2.0	200	1.06
Aug.	46 ± 1	1480 ± 30	780 ± 40	2.9	230	2.07
The relative error of the results was approx. 10%.						

2.2. Sr-90 and Cs-137 in Grass

Grass samples were collected near Thorshavn in 1965 as in the previous years. Table 2.2 shows the results. The mean S.U. content of the grass during the summer months was estimated at 915 S.U., and the mean S.U. in milk during June-August was 126 S.U. at Thorshavn (cf. 2.3), i.e. the observed ratio between S.U. in milk and in grass was 0.14 (0.12 in 1964). As compared with 1964[3], the 1965 levels in grass were on the average a little lower. As compared with Danish grass in 1965[4], we found the S.U. levels in the Faroese grass to be higher by a factor of approx. 5 in the summer months, which is in reasonable agreement with last year's observations[3]. The mean content of Cs-137 during the summer months was 3.9 nCi Cs-137/kg or 245 M.U., and O.R. milk/grass was 2.3.

The mean ratio between Cs-137 and Sr-90 in the grass (pCi/kg) was 1.8 (S.D.: 0.4), i.e. nearly equal to the ratio of 1.7 normally found in air and precipitation[6].

2.3. Sr-90 and Cs-137 in Milk

As in the previous years[1,2,3], fresh milk samples collected weekly were obtained from Thorshavn, Klaksvig and Tvørå. Sr-90 and Cs-137 were determined in bulked monthly samples.

Table 2.3.1

Sr-90 and Cs-137 in Milk from the Faroes in 1965

	Thorshavn			Klaksvig			Tvøroyri			Mean		
	S.U.	M.U.	pCi Cs-137/l	S.U.	M.U.	pCi Cs-137/l	S.U.	M.U.	pCi Cs-137/l	S.U.	M.U.	pCi Cs-137/l
Jan.	118	436	770	116	1000	1730	106	800	1400	113	861	1300
Feb.	107	413	736	148	826	1460	101	1000	1600	119	896	932
Mar.	100	700	1373	100	925	1819	122	850	1661	112	871	1617
Apr	110	572	950	122	903	1504	101	715	1194	121	713	1300
May	126	573	940	92	950	1700	107	1000	1864	111	873	1489
June	127	495	810	153	688	954	100	560	970	190	580	950
July	130	760	1256	104	930	1114	96	675	1138	130	872	1349
Aug.	111	670	770	131	933	946	83	995	1440	108	899	1054
Sept.	104	500	648	130	643	740	96	700	1104	113	598	864
Oct.	96	500	418	154	604	730	107	575	900	115	433	901
Nov.	80	360	360	130	560	800	113	800	1000	108	630	1110
Dec.	80	395	600	84	467	779	72	806	1300	80	680	990
1965	111	600	830	120	804	1102	104	800	1200	118	851	1003
The coefficient of variation of the results is approx. 20%.												

Table 2.3.2

Analysis of Variance of ln S.U. in Faroese Milk in 1965
(from table 2.3.1)

Variation	n/36 SSD	f	s^2	v^2	P
Between locations	0.3167	2	0.1583	3.81	>95%
Between months	0.3378	11	0.0307		
Remainder	0.9134	22	0.0415		
Total	1.5669	35			
$\bar{y}$ = 0.21					

Table 2.3.3

Analysis of Variance of ln M.U. in Faroese Milk in 1965
(from table 2.3.1)

Variation	n/36 SSD	f	s^2	v^2	P
Between locations	1.7467	2	0.8734	18.70	>99.95%
Between months	1.7512	11	0.1592	3.41	>99%
Remainder	1.0278	22	0.0467		
Total	4.5257	35			
$\bar{y}$ = 0.22					

Table 2.3.4

Analysis of Variance of ln pCi Cs-137/l in Faroese Milk in 1965
(from table 2.3.1)

Variation	n/36 SSD	f	s^2	v^2	P
Between locations	1.6366	2	0.8183	17.41	>99.95%
Between months	2.0274	11	0.1843	3.92	> 99.5%
Remainder	1.0329	22	0.0470		
Total	4.6969	35			
$\bar{y}$ = 0.22					

Table 2.3.1 shows the results and tables 2.3.2 - 2.3.4 the analyses of variance of the S U., M.U. and pCi Cs-137/l figures respectively. The variation between months was significant for Cs-137, but not for Sr-90. Thus the Cs-137 mean level in milk from the last quarter of the year was only two thirds of that found in the first quarter, whereas the Sr-90 level was essentially the same in the two quarters. The variation between locations was highly significant for Cs-137, but only probably significant for Sr-90. The highest Cs-137 levels were found in the milk from Tvørå and the highest Sr-90 concentrations in the Klaksvig milk.

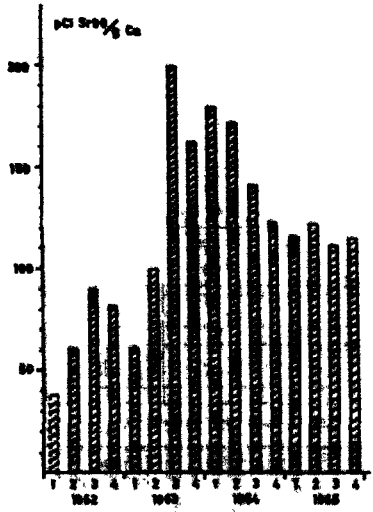

Fig. 2.3.1. S.U. in Faroese milk in 1962-65.

Fig. 2.3.1 shows the quarterly S.U. values since 1962. The annual mean values for 1965 were 115 S.U. (~ 138 pCi Sr-90/l) and 651 M.U. or 1095 pCi Cs-137/l, i.e. the 1965 Sr-90 level was 75% and the Cs-137 level 79% of the 1964 mean levels[3]; in Denmark the corresponding percentages were 70% and 49% respectively[4], which indicates that Cs-137 in the Faroes also depends upon the accumulated fall-out, which is not the case in Denmark.

The Sr-90 levels in milk from the grazing period May-October 1965 were on the average 75% of those found in the same period in 1964, and the Cs-137 mean level was 71% of that in 1964. The ratio between Sr-90 fall-out rates in the grazing periods in 1965 and 1964 was 0.86 (cf. 2.1).

The annual mean value of the M.U./S.U. ratio in Faroese milk was 4.4 at Thorshavn (5.0 in 1964), 5.1 at Klaksvig (4.9 in 1964) and 7.8 at Tværå (6.8 in 1964). The mean ratio was 5.4 during the grazing period (May-October), and in the winter time it was 5.7, i.e. only a little different, which is in agreement with the observations in 1963[2] and 1964[3].

Table 2.4.1

Sr-90 and Cs-137 in Sheep Samples from the Faroes Collected in 1965

Sampling month	Sample type	pCi Sr-90/kg	S.U.	nCi Cs-137/kg	M.U.	Remarks
Feb.	Meat	1700	1930	3.5	1380	Dried
	Bone	-	915 ± 10	-	-	
Apr.	Meat	513	940	12.6	2670	Frozen
	Bone	-	831 ± 29			
Aug.	Meat	41	96	4.5	1700	
	Bone	-	318 ± 3			
Nov.	Meat	96	911	3.7	2050	Dried
	Bone	-	452 ± 1			
Dec.	Meat	169	980	4.3	1320	Dried
	Bone	-	496 ± 27			
The relative error of the determinations is approx. 10%.						

2.4. Sr-90 and Cs-137 in Terrestrial Animals

Sheep samples were collected regularly throughout 1965. Table 2.4.1 shows the results.

The arithmetic mean values for mutton were 504 pCi Sr-90/kg or 969 S.U. and 5.7 nCi Cs-137/kg or 8120 M.U. The geometric mean values were 225 pCi Sr-90/kg (η = 2.8) or 688 S.U. (η = 1.7) and 5.0 nCi Cs-137/kg (η = 0.55) or 1770 M.U. (η = 0.30). The (arithmetic) mean S.U. level in sheep bone was 603 S.U. As compared with the levels found in 1964, the 1965 levels were somewhat higher on the average, especially the Sr-90 levels in meat.

2.5. Sr-90, Cs-137 and Mn-54 in Sea Animals

Table 2.5.1 shows the Sr-90 and Cs-137 levels in fish and sea birds collected in 1965 in the Faroes. The mean levels in fish were 1.5 pCi Sr-90/kg and approx. 24 pCi Cs-137/kg. As compared with 1964, we find the values in 1965 to be 1.5 to 2 times higher.

The mean levels in sea birds were somewhat higher than the fish levels.

Mn-54 was found in some of the samples. The mean level in fish was approx. 20 pCi Mn-54/kg, and in birds we found approx. 230 pCi Mn-54/kg.

Table 2.5.1

Sr-90 and Cs-137 in Faroese Sea Animals Collected in 1965

Sampling month	Species		Sample type	pCi Sr-90/kg	pCi Sr-90/g Ca	pCi Cs-137/kg	pCi Cs-137/g K
Jan.	Fish	Gadus callarias	Meat	1.4	11	-	-
		Gadus aglefinus*	Meat	2.7	23	51	15
Mar.		Gadus callarias	Meat	1.3	5	34	9
		Gadus aglefinus	Meat	1.3	7	42	10
June		Gadus callarias*	Meat	1.9	20	15	7
		Gadus aglefinus	Meat	4.9	13	12	5
Sep.		Gadus sp.	Meat	-	-	13	5
Nov.		Gadus callarias*	Meat	1.1	7	17	6
		Gadus aglefinus	Meat	2.2	18	8	4
June	Birds	Uria aalge	Meat	2.8	3	130	41
			Bone	-	0.33	-	-
		Fratercula arctica	Meat*	12.4	31	-	-
			Bone	-	0.37	-	-
		Uria aalge	Eggs*	1.2 ± 0.1	1.1 ± 0.1	-	-

* Samples with measurable amounts of Mn-54.

The estimated analytical error of the Sr-90 and Cs-137 determinations was approx. 20%.

2.6. Sr-90 in Drinking Water

Drinking-water samples were collected as previously[1-3]. Table 2.6.1 shows the results and table 2.6.2 the analysis of variance. The variation between locations was highly significant. The drinking water from Thorshavn contained more Sr-90 than that from Tvørå. This was also the case in 1963[2] and 1964[3].

The mean level in 1965 was 0.85 pCi Sr-90/l, i.e. 72% of the 1964 mean. The rain water in 1965 contained one third of the Sr-90 found in 1964 (cf. 2.1), i.e. the drinking water is somewhat older than the rain. This is in agreement with the results obtained earlier[2] from a comparison of the Sr-89/Sr-90 ratios in precipitation and drinking water.

Table 2.6.1

Sr-90 in Drinking Water from the Faroes in 1965, pCi Sr-90/l

Month	Thorshavn	Klaksvig	Tvøroi
Jan.	1.53	0.70	0.65
Mar.	1.68	0.96	0.77
May	1.47	0.76	0.68
July	1.22	0.77	0.55
Sep.	0.84	0.42	0.50
Nov.	1.18	0.49	0.60
1965	1.34	0.68	0.62
The coefficient of variation of the results was 18%.			

Table 2.6.2

Analysis of Variance of pCi Sr-90/l Drinking Water in 1965 (From table 2.6.1)

Variation	n/18 SSD	f	s^2	v^2	F
Between locations	1.3842	2	0.6921	38.71	> 99.95%
Between months	0.3823	6	0.0063	2.76	> 90%
Remainder	0.2609	10	0.0261		
Total	1.9674				

2.7. Sr-90 and Cs-137 in Miscellaneous Samples

2.7.1. Soil

Soil samples were collected in March and September near Thorshavn and Klaksvig. Table 2.7.1 shows the results. It is evident that the sample depth plays an important role for the activity; at Thorshavn, for instance, more than 30% of the accumulated fall-out in the soil was found below 10 cm depth, and in Klaksvig approx. 50% of the total activity was found below 5 cm. Hence we could not be sure that a sample depth of 15 cm would give us all activity accumulated in the soil. Especially as regards Klaksvig, we have a strong feeling that the accumulated fall-out by March was underestimated although the sample was taken down to 15 cm.

As the fall-out at Thorshavn from September to December was approx. 1 mCi Sr-90/km^2 and that at Klaksvig from March to December approx. 10 mCi Sr-90/km^2, the accumulated fall-out at Thorshavn at the end of 1965 was estimated at 158 mCi Sr-90/km^2 and that at Klaksvig at 180 mCi Sr-90/km^2.

Table 2.7.1

Sr-90 in Faroese Soil in 1965

	Thorshavn		Klaksvig	
	mCi Sr-90/km^2	pCi Sr-90/kg	mCi Sr-90/km^2	pCi Sr-90/kg
Mar.	90 ± 5 (10 cm depth)	2600 ± 130 (10 cm depth)	85 ± 5 (5 cm depth) 170 ± 1 (15 cm depth)	2350 ± 130 (5 cm depth) 1870 ± 10 (15 cm depth)
Sep.	157 ± 3 (15 cm depth)	2880 ± 50 (15 cm depth)	89 ± 9 (5 cm depth)	4160 ± 420 (5 cm depth)
The error term is the S.E. of double determinations.				

The amounts of fall-out at the two locations may however, also be estimated from Danish fall-out measurements. In the period 1963-65 the fall-out rates at Thorshavn and Klaksvig were 1.31 and 2.64 times higher respectively than that in Denmark in the same period. As the accumulated fall-out in Denmark[4] by the end of 1965 was 57 mCi Sr-90/km^2, we estimate the fall-out in Thorshavn at 1.31 · 57 = 75 mCi Sr-90/km^2 and that in Klaksvig at 2.64 · 57 = 150 mCi Sr-90/km^2. The great discrepancy, especially between the two estimates of accumulated fall-out at Thorshavn, might have two causes: first, the soil samples were not collected at the same place as the rain water, and secondly, run-off from neighbouring hillsides may have increased the soil level of Sr-90 at the location where the soil samples were collected.

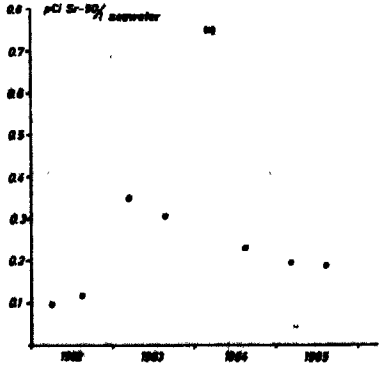

Fig. 2.7.2. Sr-90 in Faroese sea water in 1962-65.

2.7.2. Sea water

Surface sea water was collected near Thorshavn in March and August. The mean content was in March 0.19 pCi Sr-90/l or 4.3 S.U. (salinity: 34.1 o/oo) and in August 0.19 pCi Sr-90/l or 3.9 S.U. (salinity: 38.0 o/oo).

In 1965 we thus found no difference between the two samples, unlike what we saw in 1964, but in agreement with the observations in 1962 and 1963 (cf. fig. 2.7.2). The extreme value in March 1964 was probably due to contamination of the sample with rain water, as discussed in ref. 3, and is therefore in brackets in the figure.

2.7.3. Sea plants

Sea plants (Fucus sp.) collected in March contained 15 $\pm$ 4 S.U., and Fucus sp. from August contained 8.5 $\pm$ 0.1 S.U. (the error term is the S.E. of double determinations).

The mean S.U. level in 1965 was approx. the same as that in 1964[3].

Cs-137 was detectable in both samples. The March sample contained 1.5 M.U. and the August sample 3.2 M.U., i.e. approx. one third of the 1964 levels.

2.7.4. Potatoes and other vegetables

Potatoes were collected in January, March and November and cauliflower and carrots in August. Table 2.7.4 shows the results of the Sr-90 and Cs-137 determinations.

The mean level of Sr-90 in potatoes (pCi/kg) was approx. 80% higher in 1965 than in 1964[3]. The Cs-137 figures were 2.5 times higher than in 1964.

The Sr-90 as well as the Cs-137 levels in cauliflower collected in 1965 were definitely lower than in the 1964 sample. Carrots showed Sr-90 levels equal to those found in 1963[2]; the Cs-137 levels, however, were lower by a factor of four in 1965 as compared with 1963.

Table 2.7.4

Sr-90 and Cs-137 in Potatoes and Other Vegetables Collected in the Faroes in 1965

Sampling month	Sort	pCi Sr-90/kg	pCi Sr-90/g Ca	pCi Cs-137/kg	pCi Cs-137/g K
Jan.	Potatoes	97	880	460	150
Mar.		86	940	790	300
Nov.		36	1230	630	200
Aug.	Carrots	16.0 $\pm$ 0.3	87 $\pm$ 5	18	7
	Cauliflower	0.3	7.6	25	9

The relative error of the results was approx. 10% except for the pCi Sr-90/g Ca figures, where the error was probably 50% because of difficulties with the Ca-analysis.

Table 2.7.5

Sr-90 and Cs-137 in Faroese Bread in 1965

Month	White bread				Rye bread			
	pCi Sr-90/kg	pCi Sr-90/g Ca	pCi Cs-137/kg	pCi Cs-137/g K	pCi Sr-90/kg	pCi Sr-90/g Ca	pCi Cs-137/kg	pCi Cs-137/g K
June	14.1 ± 0.1	10.6 ± 0.1	156	166	95 ± 12	52 ± 6	389	394
Dec.	11.6 ± 3.4	17.9 ± 4.3	128	172	48 ± 5	33 ± 1	389	188

The error term is the S.E. of the mean of double determinations.
The relative error of the results was estimated at approx. 10%.

2.7.5. Bread

Rye bread and white bread were collected as in 1964[3] in Thorshavn in June and December 1965. The mean levels in white bread of the two collections were 12.8 pCi Sr-90/kg and 142 pCi Cs-137/kg, i.e. 88 and 75% respectively of the corresponding 1964 levels. The rye bread collected in 1965 contained on the average 71 pCi Sr-90/kg and 391 pCi Cs-137/kg, i.e. approx. 62% of the 1964 levels. The Faroese white-bread levels were approx. 57% and the rye-bread levels approx. 64% of the Danish levels in June and December 1965. There was no significant difference between the ratios $\frac{\text{Sr-90 in Faroese bread}}{\text{Sr-90 in Danish bread}}$ and $\frac{\text{Cs-137 in Faroese bread}}{\text{Cs-137 in Danish bread}}$ in 1965, as there was in 1964[3]. As suggested in ref. 3, the smaller activity content in Faroese bread is probably due to a lower extraction percentage of Faroese flour than of Danish. Faroese flour presumably also differs in age and origin from that used in Denmark.

The mean calcium content of Faroese white bread in 1964-65 was 1.0 g Ca/kg bread (in Danish white bread: 2.0 g Ca/kg) and that of Faroese rye bread 1.9 g Ca/kg (in Danish rye bread: 2.9 g Ca/kg), i.e. the amounts of creta praeparata in Faroese bread are 1/2 for white bread and 2/3 for rye bread of the amounts found in Danish bread.

2.7.6. Cheese and eggs

Cheese and eggs were collected twice from Thorshavn in 1965. Table 2.7.6 shows the results. The S.U. level in cheese corresponded approx. to that in milk from 1964[3], whereas the M.U. level was in better agreement with that in milk from 1965 (cf. 2.3).

The eggs from December were possibly of Danish origin[4], whereas those from June seem to have come from Faroese hens.

Table 2.7.6

Sr-90 and Cs-137 in Cheese and Eggs Collected in the Faroes in 1965

Month	Sample	pCi Sr-90/kg	pCi Sr-90/g Ca	pCi Cs-137/kg	pCi Cs-137/g K
Feb.	Cheese	1310 ± 30	149 ± 7	468	560
June		1695 ± 85	172 ± 20	1190	611
June	Eggs (Hens)	27 ± 7	50 ± 12	77	66
Dec.		4.5 ± 0.3	8.4 ± 0.5	12	11

The error term is the S.E. of the mean of double determinations. The estimated error of the results is approx. 10%.

2.7.7. Humans

Since 1962, shed deciduous teeth from school children in the Faroes have been collected[2].

Table 2.7.7.1 shows the preliminary results of the sampling. An analysis of variance (table 2.7.7.2) indicated a probably significant difference between tooth species (second molars showed higher levels than first molars) and a highly significant difference between years of birth (cf. also fig. 2.7.7). A comparison with preliminary data on shed deciduous teeth collected in Denmark shows that the tooth level in Faroese children born in 1950-52 was approx. 50% higher than the corresponding Danish level; for children born in the years 1953-57 the Faroese level was approx. 3 times higher. In the years 1962-65 the Faroese adult mean diet contained approx. twice as much Sr-90 as the Danish adult diet and Faroese-produced milk 6.4 times more Sr-90 than Danish milk. As milk is a more prominent component in the diet of children than in that of adults, it seems reasonable to assume, also for the years 1953-57, that the S.U. level in the diet of Faroese children was more than three times the corresponding Danish level.

Table 2.7.7.1

pCi Sr-90/g Ca in Faroese Shed Deciduous Teeth Collected in 1963

Years of birth of the children	Incisors	Cuspids	First molars	Second molars
1950	0.15	0.18	0.19	0.53
1951	0.44	0.39	0.28	0.39
1952	0.60	0.71	-	0.86
1953	1.27	0.86	0.86	0.97
1954	1.84	1.31	1.27	1.70
1955	2.40	2.12	-	3.03
1956	3.22	2.68	3.08	3.32
1957	4.09	-	4.12	4.46

The coefficient of variation of the results was approx. 20%.

Table 2.7.7.2

Analysis of Variance of ln S.U. in Faroese Teeth, 1950-57
(From table 2.7.7.1)

Variation	n/32 SSD	f	s^2	v^2	P
Between tooth species	0.7549	3	0.2516	3.80	> 95%
Between birth years	30.1118	7	4.3016	64.98	>99.95%
Remainder	1.1816	18	0.0662		
Total	32.0583				
η = 0.26					

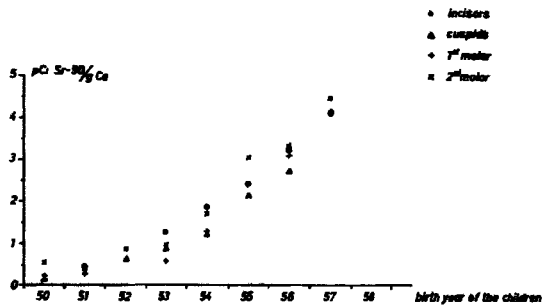

Fig. 2.7.7. Sr-90 in Faroese deciduous teeth collected in 1963.

3. ESTIMATE OF THE MEAN CONTENTS OF Sr-90 AND Cs-137 IN THE HUMAN DIET

3.1. Annual quantities

As in 1962[1], the annual quantities are based on the estimate made by Professor E. Hoff-Jørgensen, Ph. D., on the assumption of a daily per capita intake of approx. 3000 calories.

3.2. Milk and cream

75% of the milk consumed in the Faroes is assumed to be of local origin, and 25% comes from Denmark. Hence the Sr-90 content in milk consumed in the Faroes in 1965 was $1.2 \cdot (0.75 \cdot 115 + 0.25 \cdot 17.3) = 109$

pCi Sr-90/kg, and the Cs-137 content was 1.66 · (0.75 · 651 + 0.25 · 33) = 824 pCi Cs-137/kg (cf. 2.3 and ref. 4). 1 kg milk contains 1.2 g Ca and 1.66 g K.

3.3. Cheese

Nearly all cheese consumed in the Faroes is of Danish origin, and the Danish figures from ref. 4 were used: 148 pCi Sr-90/kg and 40 pCi Cs-137/kg.

3.4. Grain products

As most grain products are imported from Denmark, the Danish figures for 1965[4] were used in the calculation of the Faroese levels. Danish rye flour (100% extraction) contained 217 pCi Sr-90/kg and 796 pCi Cs-137/kg, wheat flour (75% extraction) contained 24.9 pCi Sr-90/kg and 162 pCi Cs-137/kg, and grits 50 pCi Sr-90/kg and 275 pCi Cs-137/kg. The mean daily consumption of grain products in the Faroes is 60 g rye flour, 120 g wheat flour and 20 g grits. Hence the mean concentration of Sr-90 in grain products consumed in the Faroes in 1965 becomes 97 pCi Sr-90/kg and 403 pCi Cs-137/kg. We realize (cf. 2.7.5) that these activity figures may overestimate the actual intake of Sr-90 and Cs-137 from grain products in the Faroes (cf. also 3.11).

3.5. Potatoes

All potatoes consumed in the Faroes are assumed to be of local origin. The mean values obtained from table 2.7.4 were used, i.e. 36 pCi Sr-90/kg and 627 pCi Cs-137/kg.

3.6. Other vegetables and fruit

As the amount of vegetables and fruit grown in the Faroes is limited, and as the activity in Faroese vegetables seemed to differ little from the levels found in Denmark, the Danish figures from 1965[4] were used. Thus the mean contents in vegetables other than potatoes were 16 pCi Sr-90/kg and 13 pCi Cs-137/kg (the daily per capita intake of leafy vegetables is 35 g and that of root vegetables 20 g), and the mean contents in fruit were 5 pCi Sr-90/kg and 35 pCi Cs-137/kg.

3.7. Meat and eggs

The meat and egg consumption in the Faroes is estimated to consist of 50% locally produced mutton, 25% local whale meat and 25% sea birds and eggs.

The mutton contained on the average (geometric mean) 225 pCi Sr-90/kg and 5.0 nCi Cs-137/kg (cf. 2.4). No samples of whale meat were obtained in 1965, but we estimate the activity level to have been equal to that of sea-bird meat (geometric mean), i.e. approx. 6.8 pCi Sr-90/kg and 138 pCi Cs-137/kg (cf. 2.5.1).

The mean levels in hens' eggs were 16 pCi Sr-90/kg and 45 pCi Cs-137/kg (cf. 2.7.6), and in sea-birds' eggs the Sr-90 level was 1.2 pCi/kg. Hence we estimate the mean content of Sr-90 in meat and eggs consumed in 1965 to be

$$0.50 \cdot 225 + 0.25 \cdot 6.8 + 0.25 \left(\frac{6.8 + 16 + 1.2}{3}\right) = 116 \text{ pCi Sr-90/kg}$$

and the Cs-137 content to be

$$0.50 \cdot 5.0 + 0.25 \cdot 0.1 + 0.25 \left(\frac{0.14 + 0.04}{2}\right) = 2.55 \text{ nCi Cs-137/kg.}$$

3.8. Fish

All fish consumed in the Faroes is of local origin, and the mean contents in fish, obtained from sub-section 2.5, were 1.5 pCi Sr-90/kg and 24 pCi Cs-137/kg.

3.9. Coffee and tea

The Danish figures for 1965[4] were used, i.e. 22 pCi Sr-90/kg and 77 pCi Cs-137/kg.

3.10. Drinking water

The mean value found in table 2.6 was used, i.e. 0.85 pCi Sr-90/l. The Cs-137 content was estimated to be approx. one fourth the ratio found in New York tap water in 1964[7]) of the Sr-90 content, i.e. 0.2 pCi Cs-137/l.

Tables 3.1 and 3.2 show the estimates of Sr-90 and Cs-137 respectively.

3.11. Discussion

In tables 3.1 and 3.2 the Sr-90 and Cs-137 in Faroese grain products are estimated from Danish grain levels. If the measurements of Faroese bread are used instead, the estimated mean contents of Sr-90 and Cs-137 in rye flour consumed in the Faroes in 1965 become $1.35 \cdot (72.8) = 98$ pCi Sr-90/kg and $1.35 \cdot (391) = 528$ pCi Cs-137/kg and those in wheat flour: $1.35 \cdot (12.8) = 17.3$ pCi Sr-90/kg and $1.35 \cdot (142) = 192$ pCi Cs-137/kg. (1 kg flour corresponds to 1.35 kg bread[8]). The figures in brackets are the mean values of the bread levels found in June and December 1965, cf. table 2.7.5). Hence the daily intake of Sr-90 in table 3.1 changes from 92 to 82 pCi Sr-90/

Table 3.1

Estimate of the Mean Content of Sr-90
in the Human Diet in the Faroes in 1965

Type of food	Annual quantity in kg	pCi Sr-90/kg	Total pCi Sr-90	Percentage of total Sr-90 in food
Milk and cream	146	109	15,914	47.3
Cheese	7.3	148	1,080	3.2
Grain products	80	97	7,760	23.1
Potatoes	91	36	3,276	9.7
Other vegetables	20	16	320	0.9
Fruit	18	13	234	0.7
Meat and eggs	37	116	4,292	12.8
Fish	91	1.5	136	0.4
Coffee and tea	7.3	22	160	0.5
Drinking water	548	0.85	466	1.4
Total			33,838	
The mean annual intake of calcium is estimated to be 600 g (approx. 200-250 g of creta praeparata). Hence the Sr-90/g Ca ratio in the total Faroese diet was 56.1 S.U. in 1965.				

Table 3.2

Estimate of the Mean Content of Cs-137
in the Human Diet in the Faroes in 1965

Type of food	Annual quantity in kg	pCi Cs-137/kg	Total pCi Cs-137	Percentage of total Cs-137 in food
Milk and cream	146	824	120,304	39.1
Cheese	7.3	40	292	0.1
Grain products	80	403	32,240	10.5
Potatoes	91	627	57,057	18.5
Other vegetables	20	13	260	0.1
Fruit	18	35	630	0.2
Meat and eggs	37	2,550	94,350	30.6
Fish	91	24	2,184	0.7
Coffee and tea	7.3	77	562	0.2
Drinking water	548	0.2	110	0.0
Total			307,989	
The mean annual intake of potassium is estimated to be approx. 1200 g. Hence the pCi Cs-137/g K ratio becomes 257 M.U., and the daily intake of Cs-137 was 844 pCi Cs-137.				

day and the Cs-137 intake (cf. table 3.2) from 844 to 826 pCi Cs-137/day. If furthermore we consider that the amount of creta praeparata in Faroese flour is 1/2 - 2/3 of that found in Danish flour (2.7.5), the estimated annual intake of calcium in the Faroese total diet becomes 500 g and the S.U. level

$$\frac{29,846}{500} = 59.7 \text{ pCi Sr-90/g Ca,}$$

i.e. a little higher than the level estimated in table 3.1 on the basis of the Danish grain data and a calcium consumption of 600 g per year.

As in 1962[1], 1963[2] and 1964[3], the main contributors to the Sr-90 content in the Faroese diet were milk products and grain products, which together accounted for 70.4% of the total Sr-90 content in the diet in 1965 (in 1964: 87.5%). As regards Cs-137, milk products, meat (mutton), potatoes, and grain were the most important contributors. In 1965, 98.7% of the total Cs-137 content in the diet came from these products (in 1964: 98.9%).

The Faroese mean diet contained approx. twice as much Sr-90 and four times as much Cs-137 as the Danish 1965 diet[4]. It is remarkable that the milk products and not the grain products were the most important Sr-90 contributors in the Faroese diet, unlike what was the case in Denmark.

4. CONCLUSION

4.1.

The Sr-90 fall-out rate in the Faroes in 1965 was approx. 8 mCi Sr-90/km^2. The accumulated fall-out by the end of 1965 was estimated at approx. 110 mCi Sr-90/km^2.

4.2.

The mean level of Sr-90 in Faroese milk was 115 S.U. or 138 pCi Sr-90/l. The Cs-137 concentration was 651 pCi Cs-137/g K, or 1095 pCi Cs-137/l.

Potatoes contained 36 pCi Sr-90/kg and 627 pCi Cs-137/kg. Mutton contained on the average 225 pCi Sr-90/kg and 5.0 nCi Cs-137/kg. Fish showed mean levels of 1.5 pCi Sr-90/kg and 24 pCi Cs-137/kg.

The mean content of Sr-90 in drinking water was 0.85 pCi/l.

The mean daily per capita intakes with the diet in the Faroes in 1965 were estimated at 92 pCi Sr-90 (56.1 S.U.) and 844 pCi Cs-137 (257 pCi Cs-137/g K).

4.3.

From the Faroese and Danish diet estimates and from measurements on Danish bones, the Faroese bone level in 1965 in new-born children was estimated at approx. 7 S.U., in infants (1 month - 4 years) at 15-30 S.U. (depending upon the amount of locally produced milk in the diet of the infants), in children and teenagers (5-19 years) at approx. 10 S.U., and in adult vertebrae at approx. 6 S.U.

The mean content of Cs-137 in the Faroese adult was estimated at approx. 100 nCi or approx. 700 pCi Cs-137/g K. This estimate was based on the Faroese and Danish diet estimates in 1965 and on Danish whole-body measurements.

Shed deciduous teeth from Faroese children born in 1953-57 showed S.U. levels approx. 3 times higher than the corresponding levels found in Danish teeth. The mean S.U. level in Faroese shed deciduous teeth (incisors, cuspids and first molars) increased from approx. 0.2 for children born in 1950 to 4 pCi Sr-90/g Ca for children born in 1957.

4.4.

While the Sr-90 fall-out rate in 1965 was approx. one third of that in 1964, the diet concentrations were 3/4 of and the levels in humans equal to or a little higher than the 1964 values. This is an indication both of the delay in the transference of the fall-out to the diet, and hence to the human body, and of the importance of root uptake of Sr-90 and Cs-137 in the Faroese crops and the resulting dependence upon accumulated fall-out rather than the fall-out rate.

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